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HABIT-FORMATION IN THE GREEN CRAB, *CARCINUS GRANULATUS*.

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In his excellent paper ¹ on the structure of the nervous system of *Carcinus mænas* Albrecht Bethe describes certain experiments the results of which he believes to justify the conclusion that the green crab does not profit by experience, and therefore does not possess "psychischen Qualitäten."

The following are two of the experiments by which Bethe tested the ability of *Carcinus* to learn. A crab was placed in an aquarium which contained an *Eledone* in the darkest corner. Immediately the crab scurried off into the dark region and was seized by the *Eledone* and drawn under its mantle. The experimenter then interfered by quickly freeing the crab from its enemy and returning it to the opposite end of the basin. Again the crab hurried into the shaded region, was seized, freed and returned to the light. This experiment Bethe says he repeated with one individual five times and with another six times without obtaining any evidence that the crabs were learning to avoid the danger. In another test crabs in a basin were baited with meat, and each time they tried to get the food they were seized and maltreated by the experimenter. Thus an attempt was made to teach them that meat, under certain conditions, meant danger. But in this test also several repetitions of the experiment failed to teach the crabs to avoid the danger.

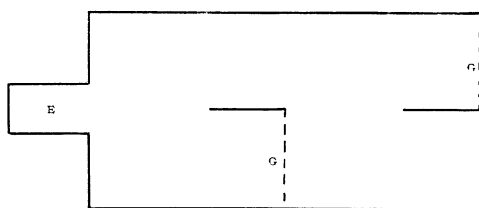
Bethe's tests are unsatisfactory because in each he attempts to inhibit an instinctive action. In the first test the animal naturally sought to hide in the dark; and it would be absurd to expect to modify this instinct by giving the animal five, six or even twenty-five experiences of the disagreeable consequences of going into the neighborhood of the *Eledone*. And in the second test the reflex food-seeking reaction to a particular kind of chemical

¹ Bethe, Albrecht: Das Centralnerven-system von *Carcinus mænas*. II. Theil., Arch. f. Microscop. Anat., Bd. 51, 1898, S. 447.

stimulation stood in the way of the establishment of new modes of response.

Bethe should not have expected a few experiences to modify or inhibit such fundamentally important reactions as those to light and to food. Almost any reaction can be modified if time enough be devoted to that end, but it is as unlikely that a crab would learn to avoid the dark or to inhibit its food-taking reaction after a half dozen harmful experiences in a certain situation as it is that the grasshopper would learn to inhibit its jumping by a few experiences in a glass box. For the modification of such reactions hundreds, not tens, of experiences are necessary.

In view of the obvious unfairness of Bethe's tests of *Carcinus* I have made a further study of the ability of the American species of *Carcinus*, *C. granulatus*, which is similar to the European form, *C. maenas*. My effort has been to determine whether



Floor Plan of Experiment Box. Scale one eighth.

the animals can learn (1) a simple labyrinth path to their food, and (2) to avoid the unpleasant experience of being captured in a hand-net and taken from the aquarium.

The crabs were kept in an aquarium about 60 cm. long, 38 cm. wide and 35 cm. deep, over which an experimenting box 40 cm. \times 20 \times 12 was placed so that its exit passage just touched the surface of the water. The accompanying cut which is the floor plan of the box, shows, in addition to the entrance passage *E*, in which the crab was placed by the operator at the beginning of each experiment, two alleys which were closed by glass plates *G*, *G*. Experiments were made to discover whether the green crab would learn to avoid these blind alleys in its efforts to get back to the water of the aquarium, and if so how quickly it would learn.

The only motive relied upon for the return of the crab to the aquarium from the experimenting box was its desire to get into the water.

For two weeks several crabs were given on an average four trials per day in the labryrinth. At the beginning of the work they frequently wandered in the entrance passage and blind alleys several minutes before they succeeded in escaping, but after twenty or thirty trials most of them were able to escape directly. I was unable to get any satisfactory quantitative expression of the rapidity of learning because of the great variation in strength of the animal's desire to get back to the water; at one time it would move about constantly until it found the exit, at another it would rest quietly in the passages for long periods. In the case of an animal which, for a month, was given two trials per day in the labyrinth, the escape at first took about five minutes, and at the end of the period about ten seconds.

At first the crabs when placed in the box and poked with a stick scurried off into a corner and took a defensive position, whereas, after a few escapes from the box, they made directly for the exit as soon as they were threatened with a stick.

Even fifty experiences, in case of most of the individuals studied, did not result in the formation of a perfect habit.

Further tests of the ability of the green crab to learn were made by placing a wire-screen partition in the middle of the aquarium and allowing the animals to find their way through an opening in the screen to food on the opposite side. Since the crabs tend to follow the edge of such a screen, the opening, 10 cm. x 10, was made in the middle of the screen. It was therefore about 12 cm. distant from the sides, top and bottom of the aquarium.

In this test each crab was given a single experience per day. To provide the animals with a motive for seeking to pass beyond the screen, at the beginning of each trial a piece of fish meat was placed in the corner of the aquarium diagonally opposite to that from which the crab started. The meat having been placed, a crab was put into the aquarium, and a record was kept of its wanderings in search of the food, and of the time occupied in finding it.

The following are the results of ten trials with two animals.

Number 1.		Number 2.	
Trial.	Time in Minutes.	Trial.	Time in Minutes
1	7	1	23
2	4	2	10
3	3 $\frac{1}{2}$	3	4 $\frac{1}{2}$
4	4	4	3
5	2	5	2 $\frac{1}{4}$
6	1	6	6 $\frac{1}{2}$
7	1	7	7
8	1 $\frac{1}{2}$	8	1 $\frac{1}{4}$
9	1	9	1 $\frac{1}{5}$
10	1 $\frac{1}{4}$	10	$\frac{1}{2}$

Crab number 1 almost invariably moved directly toward the meat and searched for an opening in the screen along the side of the aquarium nearest the meat, thence it would move to the middle of the screen and find the opening. Number 2 just as uniformly followed the edge of the screen, climbing up one side, along the top, down the other side, and across the bottom ceaselessly until it chanced to get near the opening.

The paths for the first trials were complex and devious, but in the later trials they were almost direct lines to the meat.

There was little evidence of the use of vision in the finding of the opening in the screen. The animals seemed to be directed chiefly by the stimulus from the food.

Additional evidence of the ability of *Carcinus* to profit by experience is furnished by the following observation. It was the habit of the experimenter to catch the animals in a hand-net, take them from the water and use them for various experimental purposes. At first the crabs did not react otherwise to the approach of the experimenter with the net than to other large objects, but after a few days it became much more difficult to capture them for they had learned to avoid the net.